

# Age structure of *Tilia* broad-leaved Korean pine forest on northern slope of Changbai Mountain<sup>1</sup>

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**Abstract** Based on a vast of field investigation on stamps in *Tilia* broad-leaved Korean pine forest on northern slope of Changbai Mountain, age structure of some major species were studied in this paper. The results showed that Korean pine population was composed of grouped patches with different ages. There were not strict intervals among the dominated generations, and the curve of age structure often had two or more peaks. The distribution of broad-leaved species in natural Korean pine forest was grouped or scattered, and age distribution was also uneven-aged. There existed close relation between quantity of broad-leaved species and Korean pine. So, it shaped multi-storied and uneven-aged mixed forest. The model of age structure and growth demonstrated their passive correlation, but growth became slow when woods had reached old age.

**Key words:** *Tilia* broad-leaved Korean pine forest, Age structure, Changbai Mountain

## Introduction

Age structure of trees, which reflects regeneration process and velocity, means quantity of trees dividing by age. Broad-leaved Korean pine forest was the typical zonal vegetation of Changbai Mountain in Northeast China, and it was the primary gymnosperm community survived after the Quaternary Glacier Period. A lot of community information accumulated in the structure of forest stands and growing process of individual trees. So, a thorough study on age structure and its distribution of broad-leaved Korean pine forest would provide theoretical basis for managing forest stands, selecting reasonable cutting size-class and reforestation. In this paper, age structure and distribution were studied mainly on *Tilia* broad-leaved Korean pine forest, which distribute widely.

## Study area and methods

### Study area

*Tilia* broad-leaved Korean pine forest is a major type of broadleaved Korean pine forest and distributed widely between elevation of 500 m and 1000 m in Changbai Mountain. The sites are mainly on smooth slope and de-watering well. The weather is temperate and the yearly average temperature is 0.9~4.0 °C. The annual precipitation is 630~780 mm and centralized in June, July and August. It is the typical temperate zonal continental climate and influenced by east maritime monsoon. It is characterized by warm, wet summer and cold, dry winter. The soil is dark brown forest soil developed on the volcanic ash<sup>[1,5]</sup>.

The typical *Tilia* broadleaved Korean pine forest, which has abundant species and complex structure, is multi-storied and uneven-aged. For example, in the sampling plot No. 1, the structure of forest stand consists of 3 *Pinus*, 3 *Tilia*, 1 *Acer*, 1 *Cudrania*, 1 *Fraxinus* and 1 else species. The numbers of trees are 300~400 ind./hm<sup>2</sup> and the total volume is 400~500 m<sup>3</sup>/hm<sup>2</sup>. The canopy coverage is 0.9. The coverage of shrub layer is 0.4 and the coverage of herb layer is 0.8<sup>[2,4]</sup>.

## Methods

### Field investigation

Field investigation was conducted on northern slope of Changbai Mountain. Annual growth rings of stamps were investigated in *Tilia* broad-leaved Korean pine forest cutover land of Hongshi Forestry Farm, Baihe Forestry Bureau, Jilin Province and the investigating time was in the second year after cutting. Sketch map of stamp location was drawn. Tree species and rotten trees were recorded. The sampling area was 2 hm<sup>2</sup>. The soil was dull brown forest soil. Elevation was 700 m. The species composition was 1 *Pinus*, 1 *Tilia*, 4 *Acer*, 2 *Ulmus*, 1 *Pterocarya*, 1 *Fraxinus* and sporadic *Picea*, *Abies*, *Cudrania* and some other sub-tree species. The density of trees was more than 300 ind./hm<sup>2</sup>. Another sampling site was located in Heping Forestry Farm, Baihe Forestry Bureau and the area was 10 hm<sup>2</sup>.

### Model of age structure and growth of major species

Equation 
$$V = at + \frac{\lambda}{2}t^2 - \frac{\lambda P}{6T}t^3 + d$$
 was used to

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simulate the relationship between age and growth. In this equation,  $V$  was growth of trees,  $T$  was maximum age that trees could reach,  $\lambda$  and  $P$  were constants,  $a$  and  $d$  were parameters.

## Results and discussion

### Age structure of Korean pine and its major companion species

#### Quantity of Korean pine distributing by age

According to age structure of Korean pine and major companion species (Table 1), Korean pine was a longevity species. The maximum age could reach to 390a and to 130 cm in diameter. The minimum age was 100a and the diameter was 30 cm. The ecological life span of Korean pine was 400a and the dominated age was 125~250a. It is obvious that Korean pine forest was uneven-aged. If 40a

was thought as a new generation, Korean pine was multi-generation gregarious and there were not strict intervals among the dominated generations. The distribution of quantity by age was scatter because Korean pine was uneven-aged, and there often existed two or more peaks (Fig. 1-A). In the same forest stand, an important characteristic of Korean pine was that the age was very different.

Table 1. The age structure of *Pinus koraiensis* and its companioned trees

Species	Max. age	Min. age	Dominated age	Rate of dominated
<i>Pinus koraiensis</i>	390	100	125-250	72
<i>Tilia amurensis</i>	240	36	75-125	48
<i>Ulmus propigua</i>	290	39	80-135	62
<i>Acer mono</i>	283	23	50-100	60
<i>Fraxinus madshurica</i>	228	58	75-125	46
<i>Betula costata</i>	284	51	75-130	47

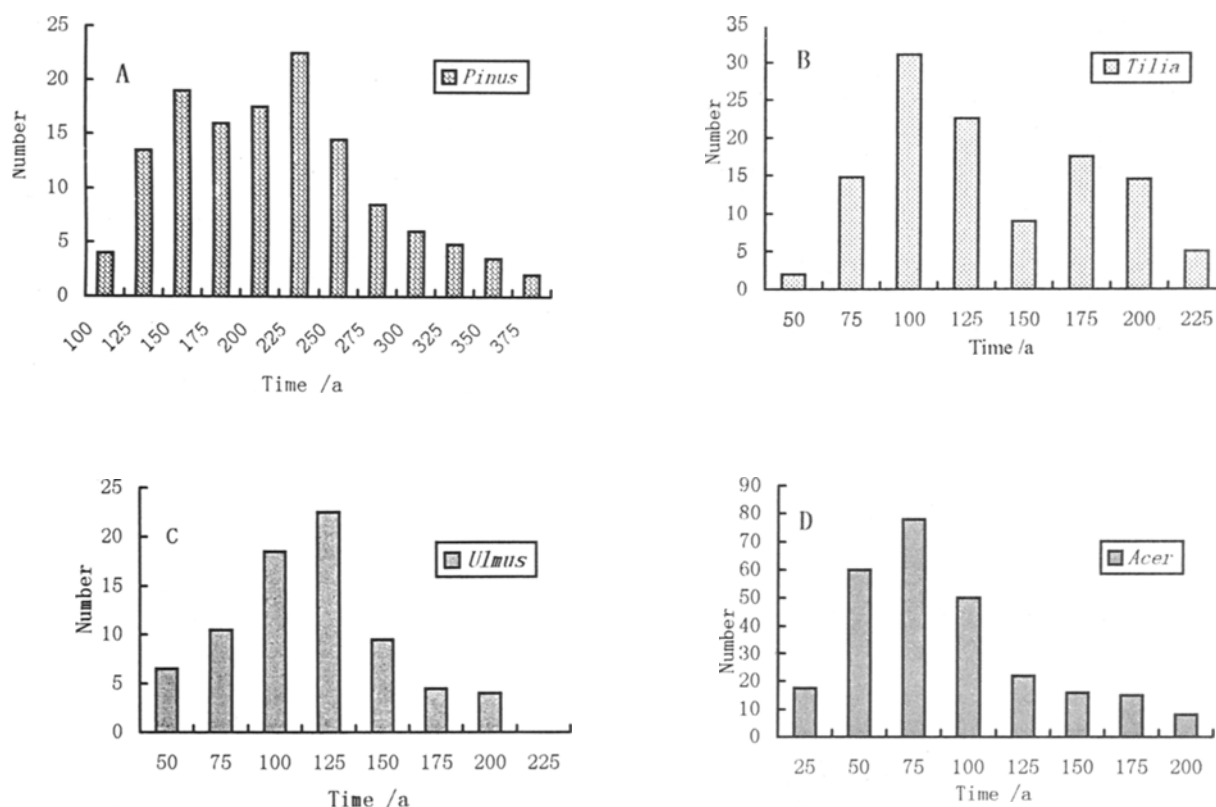


Fig.1 (A-D) Age structure of Korean pine and its major companion species

Sketch map of stamp location was drawn with age of Korean pine (Fig.2). Patches with different age were distributed unevenly. In sum, Korean pine forest was composed of uneven inlaid patch with different age in a large area. With the old trees died and fallen, gaps were formed and the forest refreshed in the gaps. It reflected uneven-aged change and structure characteristics of Korean pine

forest.<sup>[7]</sup>

#### Quantitative distribution by age of major companion species

*Tilia* was a good companion species for Korean pine. According to the data from forest stand investigation, the maximum age of *Tilia* was 220a and the diameter was 72

cm. The dominated age was 75~125a with 54% trees distributing in this age scope. There were few trees with age less than 80a, and 27% trees were in 180~210a. There were two obvious peaks in the quantity distribution by age (Fig.1-B), and few trees were of else age. It showed that *Tilia* had a long life-span. *Tilia* of 170~210a were companions for Korean pine with the similar age. *Tilia* in ages lower than 125a were younger than Korean pine around and mixed with Korean pine. The relationship between *Tilia* and Korean pine was mutual accelerating and restricting.

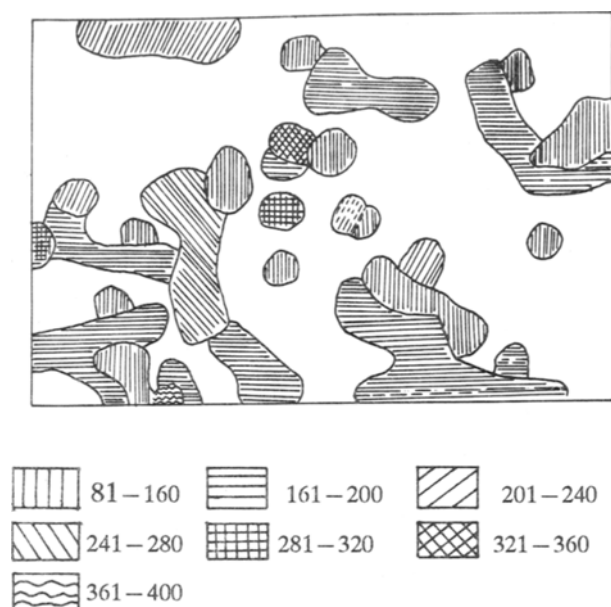


Fig.2 Distribution of age structure of Korean pine

The dominated age of *Ulmus* was 80~135a with 62% trees distributed in it. The maximum age was 290a and the diameter was 98 cm. The minimum age was 39a and the diameter was 10 cm. 9% *Ulmus* was lower than 80a and 29% older than 135a. This showed that *Ulmus* also had a long life-span. When age was lower than 135a, Korean pine increased and *Ulmus* decreased. If *Ulmus* was near Korean pine, and with age increasing, *Ulmus* could not compete over Korean pine and died increasingly.

The dominated age of *Acer* was 50~100a with 60% trees distributing in the range. The maximum age was 283a and the diameter was 53 cm. *Acer* of old age was fewer. There was only one peak in quantity distribution by ages (Fig.1-d) and this peak was higher. The proportion of *Acer* in broad-leaved trees was the highest and the age of *Acer* was lower in the forest stands.

The maximum age of *Fraxinus* was 228a and the diameter was 82 cm. The minimum age was 85a. The dominated age was 75~125a with 46% trees distributing in it, and 25% *Fraxinus* were in 150~180a. So there existed two obvious peaks (Fig.1-c). It showed that *Fraxinus* was a long life-span species. Near the *Fraxinus* of age above 200a, the age of Korean pine was in the similar age as

*Fraxinus*, and the two species reached a relative balance through long-term competition.

The regeneration of *Pterocarya* depended on old trees. The maximum age of *Pterocarya* was 284y and the minimum was 51y. 47% *Pterocarya* were in 70~130a. *Pterocarya* of age above 130y distributed evenly by age. In each age class, *Pterocarya* was fewer in number, but they did exist. It showed that *Pterocarya* produced enough seeds and refreshed easily. So *Pterocarya* often filled up the gaps.

Judging from above-mentioned, Korean pine was a long life-span species and communal with multi-generations. The dominated age of Korean pine was 125~250a, and the dominated age of broad-leaved trees was about 50~135a. When Korean pine was young, broad-leaved trees were companion species. When Korean pine was old, according to the distance between trees, the competition could result in a relative balance in the mixture. So, it shaped in uneven-aged characteristics of *Tilia* broad-leaved Korean pine forest.

### Correlation between age and growth of major companion species

The ages of same tree species with same diameter were often different because the site condition and habitats of trees were different. But, in view of entirety, there existed certain correlation between age and diameter, and age of trees was often estimated by diameter in forest management and forestry production.

Fig.3 (a-d) shows the relationship between growth and DBH of 4 major species in *Tilia* broad-leaved Korean pine forest. The equations of correlation between age and volume were as follows.

For Korean pine:

$$Y_P = 49.9063 + 2.4153X - 0.0009X^2 \quad (R_P = 0.79)$$

For *Tilia*:

$$Y_T = -8.9039 + 3.7809X - 0.0142X^2 \quad (R_T = 0.78)$$

For *Fraxinus*:

$$Y_F = 48.0427 + 3.6841X - 0.0015X^2 \quad (R_F = 0.81)$$

For *Acer*:

$$Y_A = 3.4254 + 3.7567X - 0.0143X^2 \quad (R_A = 0.87)$$

Where:  $Y$  means volume and  $X$  means age.

The results showed that there existed passive correlation between growth and size class. When tree was young, growth was gradually slow down. With age increasing, diameter increased and the volume increased faster. When tree was old, it grew slowly and then stops growing. In general, the growth phase of Korean pine was long. When DBH was above 70 cm and age was above 350a, Korean pine grew slowly, and passive correlation between age and DBH decreased. Growth of *Fraxinus*, like growth of *Tilia*, was increased smoothly when DBH was about 30 cm.

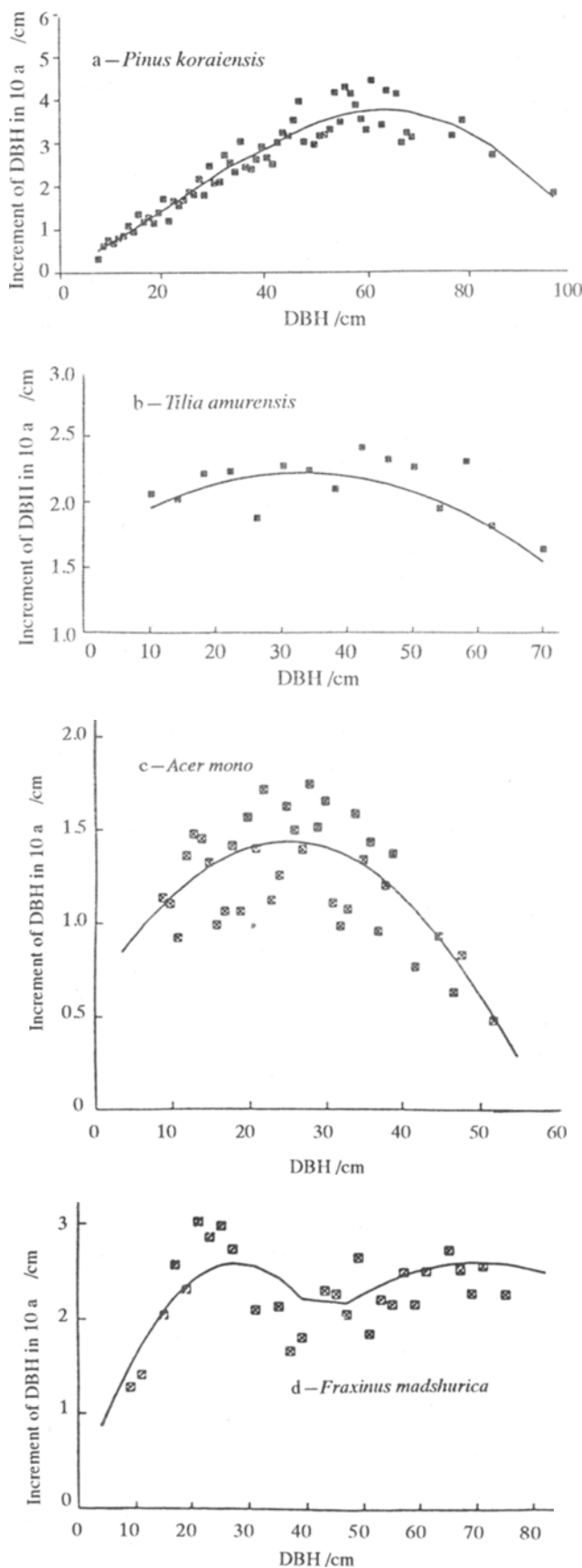


Fig. 3. Model simulation on DBH and growth

a—*Pinus koraiensis*; b—*Tilia amurensis*  
c—*Acer mono*; d—*Fraxinus madshurica*

## Conclusion

- Korean pine and broad-leaved trees were even-aged companions and uneven-aged mixed in *Tilia* broad-leaved Korean pine forest, so it shaped multi-storied and uneven-aged mixed forest in which multi-generations were communal.
- There often existed two or more peaks in age structure of Korean pine. The dominated age of *Tilia* and *Fraxinus* were longer among broad-leaved tree species. *Tilia* and *Fraxinus* were major companion species of Korean pine. The dominated age of *Ulmus* was lower. With age of *Ulmus* and quantity of Korean pine increasing, *Ulmus* died increasingly. The dominated age of *Acer* was the lowest, and a certain number of *Acer* was lower than the dominated age. The age structure of *Pterocarya* was complex and there were some trees in each age class. It showed that *Pterocarya* produced more seeds and refreshed easier than other species.
- The model of age and growth showed there existed passive correlation between them. But growth became slow when trees were old.

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